

A6 ARCHITECTURE

PEDAL-ELECTRIC HYBRID PASSENGER VEHICLE

COMPLETE ENGINEERING FEASIBILITY & DESIGN STUDY

Document Reference: A6-ENG-001-REV1
Classification: Engineering Study – Conceptual Design Phase
Prepared by: Vehicle Systems Engineering Division
Date: June 2026

EXECUTIVE SUMMARY

This document presents a complete multi-disciplinary engineering feasibility study for the A6 Architecture — a four-passenger pedal-electric hybrid vehicle. The study covers powertrain, structural, ergonomic, electrical, safety, and commercial dimensions. It evaluates whether muscular energy harvested from all four occupants, stored in a lithium-ion battery matrix, can propel the vehicle at up to 50 km/h. The analysis reveals both significant engineering potential and fundamental physical constraints that must be resolved before prototype development.

1. INTRODUCTION & CONCEPT OVERVIEW

The A6 Architecture is a conceptual four-passenger vehicle in which every occupant contributes muscular pedaling energy. That energy is harvested mechanically, converted to electricity via an onboard generator, stored in a modular lithium-ion battery pack, and finally delivered to a high-torque traction motor driving the rear axle. The concept differs fundamentally from a velomobile or a cargo-cycle because it targets automotive performance envelopes — four adult occupants, weather protection, safety structures, and sustained speeds up to 50 km/h.

This study is structured across nine technical domains: human power physics, mechanical drivetrain, energy conversion and storage, structural chassis, dynamics and control, ergonomics, electrical safety, regulatory compliance, and commercial viability. Each domain is analysed independently and then reconciled in a systems-integration assessment.

Key Design Thesis

Shared Exertion, Clean Transport — four passengers continuously pedaling at moderate effort (~150 W each) produce a combined 600 W of sustained mechanical power. After conversion losses this yields approximately 450 W to the battery and motor, enabling real-world urban speeds without any combustion energy.

2. HUMAN POWER PHYSICS & ENERGY BUDGET

2.1 Baseline Human Power Output

Human power output is well characterized by exercise physiology. The following figures represent realistic sustained outputs for a healthy adult passenger:

Effort Level	Power Output (W)	Sustainable Duration
Light (leisure)	60 – 100 W	Indefinite

Effort Level	Power Output (W)	Sustainable Duration
Moderate (brisk)	100 – 200 W	> 60 minutes
Hard (athletic)	200 – 350 W	15 – 30 minutes
Sprint	400 – 1000 W	< 30 seconds

For design purposes, a conservative sustained figure of 150 W per passenger is used. With four passengers this yields:

Combined Power Budget

4 passengers $\times$ 150 W = 600 W gross mechanical input

Generator efficiency ~80%: 480 W electrical output

Power electronics losses ~5%: ~456 W net to battery/motor

Motor-to-wheel efficiency ~90%: ~410 W tractive power

At 50 km/h (13.9 m/s) the force available at the wheel = $410 / 13.9 \approx 29.5$ N

2.2 Rolling Resistance & Aerodynamic Drag Analysis

To validate whether 410 W is sufficient for 50 km/h, the resistive forces on the vehicle must be quantified. The A6's estimated mass is 280 kg (vehicle) + 4 $\times$ 80 kg (passengers) = 600 kg gross.

Resistance Component	Formula / Value	Result at 50 km/h
Rolling resistance ($C_{rr} = 0.012$, tarmac)	$C_{rr} \times m \times g = 0.012 \times 600 \times 9.81$	70.6 N
Aerodynamic drag ($C_d = 0.35$, $A = 1.8$ m ²)	$0.5 \times 1.225 \times 0.35 \times 1.8 \times 13.9^2$	83.2 N
Total resistance force	$70.6 + 83.2$	153.8 N
Power required at 50 km/h	$153.8 \text{ N} \times 13.9 \text{ m/s}$	2,138 W

Critical Finding — Power Gap

Four passengers at moderate effort supply approximately 410 W tractive power. Cruising at 50 km/h requires approximately 2,138 W. This is a 5.2× deficit at full speed. The battery must bridge this gap. The vehicle can sustain 50 km/h for a limited time from stored charge and reach ~22 km/h on pedal power alone. This transforms the architecture from 'fully pedal-powered' to 'pedal-assisted electric vehicle' — which is the commercially correct framing.

3. MECHANICAL DRIVETRAIN — SUBSYSTEMS A6-D1 & A6-D2

3.1 Precision Crank Assembly

Each of the four occupant stations requires an independent crank-pedal assembly connected to the central drive shaft via a chain-and-sprocket or toothed belt system. The design priorities are: independent cadence adjustment per seat, force multiplication through sprocket ratio selection, and structural integration with the chassis without lateral interference.

Crank Arm Length	170 mm (standard adult ergonomic optimum; adjustable 155–185 mm)
Primary Sprocket	48T chainring, CNC-machined 7075-T6 aluminium alloy
Secondary Sprocket (drive)	12T–28T cassette, 8-speed indexed shifter per station
Drive System	Heavy-duty 1/2" × 3/32" roller chain (BMX/e-bike spec), 250 N minimum rated load
Transmission Ratio Range	1.7:1 to 4.0:1 providing pedal-equivalent gear range of ~30–80 RPM input
Crankset Bearing	Cartridge-type square-taper BB, IP67 sealed, 5,000 hr MTBF
Power Confluence	All four chains drive a common 48T collector sprocket on the unified drive shaft

3.2 Harmonic Balancer & Central Flywheel

Human pedaling is inherently pulsed — two power strokes per revolution with near-zero torque at top/bottom dead center. Without a flywheel, the generator experiences high torque ripple, reducing generator lifespan and output quality.

- Flywheel mass: 4 kg cast iron disc, 250 mm diameter, mounted on central drive shaft
- Moment of Inertia: $\sim 0.031 \text{ kg}\cdot\text{m}^2$ — sufficient to store ~ 2 revolution-equivalents of energy
- Harmonic balancer: rubber-dampened hub between flywheel and generator input shaft, absorbs $\sim 15\%$ torque spike amplitude
- Bearing housing: sealed angular-contact ball bearings, grease-lubricated, rated 10,000 hr
- Drive shaft: 25 mm diameter 4130 chromoly steel, FEA validated for combined torsional and bending loads

Engineering Note — One-Way Clutch Mechanism

Each crank station must incorporate a sprag-type one-way clutch (freewheel) so that if one or more passengers stop pedaling, the drive shaft continues to turn unimpeded by the stationary crank assembly. Without this feature, one idle passenger would act as a braking load on the entire system.

4. ENERGY CONVERSION & STORAGE — SUBSYSTEMS

A6-D1, A6-D6, A6-D7, A6-D8

4.1 Mechanical-to-Electrical Transducer (Generator)

The generator is the critical energy conversion interface. It receives variable mechanical rotation from the central flywheel and outputs regulated DC electrical power.

Parameter	Specification	Rationale
Generator Type	Permanent Magnet Synchronous (PMSG)	Highest efficiency (92–96%) at variable RPM
Rated Power	1,000 W continuous	Headroom above 600 W peak input
Peak Power	1,500 W (short-term)	Accommodates sprint input burst
Output Voltage	48–72V DC (after rectification)	Matches battery nominal voltage
Operating RPM	200–800 RPM (input shaft)	Matches flywheel speed range
Rectifier	3-phase full-wave MOSFET bridge	< 1.5% conduction loss
Efficiency (at 600 W load)	$\sim 92\%$	Industry benchmark for PMSG at part-load
Cooling	Aluminium fin housing, passive convection + forced air duct	Prevents thermal derating

4.2 Battery Management System & Pack Specification

The lithium-ion battery serves as the primary energy reservoir and determines the vehicle's range, acceleration capability, and overall energy independence from pedaling input.

Cell Chemistry	LFP (Lithium Iron Phosphate) — chosen for thermal stability, cycle life > 3,000 cycles, and tolerance to partial-state-of-charge operation
Pack Designation	6S135P configuration (notional): 72V nominal, ~20 Ah capacity = 1.44 kWh usable
Nominal Voltage	72V (LFP: 3.2V × 6S × 3.75 cells = adjusted to target)
Capacity	1.44 kWh usable; ~1.6 kWh gross (10% protection buffer each end)
Continuous Discharge Rate	3C = 60A continuous; 6C peak for acceleration
Charge Rate	0.5C from generator (≈30A) — safe for LFP
Thermal Management	Cool-plate aluminum channels, glycol-water loop, operating window 10–45°C
BMS Functions	Cell-level voltage monitoring, balancing (passive/active), temperature cutoff, SOC estimation, CAN-bus communication to ECU
Pack Weight	~18–22 kg (including housing and BMS electronics)
Range Estimate	~25–35 km at 30 km/h (battery-assist mode); ~8–12 km at 50 km/h

4.3 Power Control Unit & Inverter

The PCU/Inverter mediates between the battery and the traction motor, and coordinates with the ECU for torque management.

- Type: 3-phase IGBT inverter, 72V bus, 5 kW peak rating
- Control algorithm: Field-Oriented Control (FOC) for precise torque response at all speeds
- Regenerative braking: regen torque set by brake pedal position sensor, up to 1,500 W recovery
- Efficiency: >95% across 20–100% load range
- Protection: over-current, over-voltage, under-voltage, and thermal shutdown

5. STRUCTURAL & CHASSIS ENGINEERING — SUBSYSTEMS A6-D3 & A6-D4

5.1 Space-Frame Chassis (A6-GEMA 7)

The chassis is the most safety-critical structure. It must protect four occupants in low-speed collision events (the vehicle's target speed range), mount the pedal assemblies rigidly, and minimize weight to stay within the power budget.

Attribute	Specification	Target
Frame Material	4130 Chromoly steel tubular space-frame	Strength-to-weight optimum at < \$50K tooling cost
Secondary Panels	3 mm 6061-T6 aluminium monocoque panels	Torsional stiffness supplement
Design Method	Finite Element Analysis (FEA) — static, dynamic, crash scenarios	2× safety factor on all load paths
Wheelbase	2,200 mm	Stability at 50 km/h, turning radius < 6 m
Track Width	1,450 mm front / 1,400 mm rear	Rollover stability, CGH < 600 mm
Kerb Weight Target	250 – 300 kg	Critical to power budget feasibility
Crash Structure	Aluminium honeycomb crumple zone front and rear	ODB 40 km/h survivable
Torsional Stiffness	> 5,000 Nm/degree	Acceptable for an urban-speed vehicle
Assembly Method	TIG welded, jigged and fixture-controlled	< 3 mm dimensional tolerance

5.2 Suspension & Steering Kinematics

At 600 kg GVW, bicycle-derived suspension is insufficient. Proper four-wheel independent suspension is required for occupant comfort and vehicle dynamics.

- Front suspension: MacPherson strut or double-wishbone, 80 mm travel, spring rate 18–22 N/mm
- Rear suspension: Trailing arm with coilover, 90 mm travel, spring rate 20–25 N/mm per side
- Steering: Rack-and-pinion, manual (no power assist needed at < 50 km/h), ratio 14:1

- Brakes: Hydraulic disc brakes all four corners (cable actuation acceptable at < 50 km/h), integrated regen control
- Tyres: 145/70 R13 or similar narrow LCV tyre, rolling resistance optimized ($C_{rr} \leq 0.012$)
- Wheels: 13" × 4.5J cast alloy, weight target < 3 kg per corner

6. HIGH-TORQUE TRACTION MOTOR — SUBSYSTEM A6-D9

The traction motor drives the rear axle through a fixed-ratio gearbox. Its specification is derived from the maximum performance requirements and the battery voltage architecture.

Parameter	Specification	Notes
Motor Type	PMSM (Permanent Magnet Synchronous)	Best torque density for the weight target
Continuous Power	3 kW	Sufficient for 50 km/h on flat with battery support
Peak Power	6 kW (30 s)	For hill starts and acceleration
Continuous Torque	45 Nm	At rear wheel via 1:5 reduction gearbox
Peak Torque	90 Nm	0–30 km/h launch feel
Operating Voltage	72V nominal	Matches battery pack
Top Speed (mechanical)	55 km/h (electronically limited to 50 km/h)	Speed-by-design governed
Motor Mass	8 – 12 kg	Rear-axle integrated hub or inline geared
Cooling	IP67 sealed, forced air from traction cooling loop	Prevents derating on climbs
Efficiency (at rated load)	~92%	PMSM industry standard

7. HUMAN-MACHINE INTERFACE & ELECTRONIC CONTROL — SUBSYSTEMS A6-D7 & A6-D8

7.1 Ergonomic Pedal Interface Design

Passenger fatigue is the primary operational constraint. Each pedal station must accommodate a range of anthropometric dimensions and allow comfortable, efficient pedaling for urban trip durations (typically 10–30 minutes).

- Seat-to-pedal distance: fully adjustable fore-aft 150 mm range on linear rails
- Pedal height: fixed per seat position; three discrete positions accommodating inseam 700–950 mm (5th–95th percentile adults)
- Handlebar/grip rail: provides upper-body brace for power transfer without fatiguing the arms
- Cadence display per station: simple LED ring showing current RPM in green (optimal 60–90 RPM) or red (over/under)
- Torque sensing: strain gauge on each crank arm outputs real-time power data to the ECU and dashboard

7.2 Unified ECU Architecture

The central ECU integrates all subsystem inputs and manages energy flow, safety, and performance modes.

ECU Input Signals

Individual torque/power from 4 crank sensors | Battery SOC and temperature from BMS | Motor speed and current from inverter | Brake pressure sensors (4 corners) | Vehicle speed (wheel speed sensor) | Accelerator pedal position (driver station) | Traction control sensor | Ambient temperature

ECU Output Signals

Motor torque demand to inverter | Regenerative braking level to inverter | Generator field current (if variable-field type) | Dashboard display bus (CAN) | Thermal management pump/fan control | Over-speed and safety cut-off relay

7.3 Operating Modes

Mode	Description	Battery Role
URBAN CRUISE	Pedal + motor blend for 25–35 km/h steady state	Trickle discharge
SPRINT ASSIST	Full battery + full pedal for acceleration to 50 km/h	Active discharge
REGEN COAST	Motor regenerates during downhill / deceleration	Charging
PEDAL ONLY	Battery depleted, pedal alone, limited to ~22 km/h	Idle
STATIONARY CHARGE	Occupants pedal while stationary to pre-charge battery	Fast charge input

8. SAFETY ENGINEERING & REGULATORY COMPLIANCE

8.1 Occupant Safety

- 3-point seatbelts at all four positions — mandatory for any road-legal vehicle
- Rollover protection: integrated roof hoop in space-frame, minimum 3× occupant head clearance under roof crush
- Side intrusion beams: 50 mm OD 4130 steel tubes integrated into door surround, absorb 30 kJ
- Frontal crash: aluminium honeycomb deformable element, 200 mm stroke, 50 kJ energy target
- Windscreen: laminated safety glass, flush-mounted, 5° rake for aero benefit

8.2 Electrical Safety

- HV isolation monitoring: continuous 500V insulation resistance monitoring, < 100 kΩ/V fault threshold triggers shutdown
- Manual Service Disconnect (MSD): accessible without tools, isolates battery from all HV circuits
- Orange HV cabling: per FMVSS 305 / ECE R100 requirements
- Contactor pre-charge circuit: prevents inrush current damage to capacitors at startup
- Crash sensor: 25g impact accelerometer disconnects main HV contactor within 50 ms of collision

8.3 Regulatory Classification

The A6's regulatory classification varies by jurisdiction and is a critical commercial decision:

Jurisdiction	Likely Classification	Key Requirement
European Union	L7e Heavy Quadricycle (< 400 kg unladen, < 15 kW)	ECE R100 (battery), WVTA type approval
India (BIS / AIS)	Quadricycle (AIS-138 framework)	CMVR type approval, ARAI testing
United States	Neighborhood Electric Vehicle (NEV) / LSV < 72 km/h	FMVSS 500, state-level road access
United Kingdom	Quadricycle / L7e equivalent	DVSA MSVA scheme or full IVA

9. THERMAL MANAGEMENT SYSTEM

Thermal management is often underestimated in small EV development. The A6 has three primary heat sources: occupant body heat (~4 × 80 W metabolic waste = 320 W), battery/power electronics (~50–80 W at typical loads), and the traction motor (~30–60 W at cruise). In a sealed passenger cabin, this creates a significant cabin heating load.

- Battery thermal loop: independent 12V glycol pump, aluminium cool-plate under battery pack, front-mounted radiator (200 × 300 mm sufficient at < 60 km/h)
- Cabin ventilation: forced-air HVAC with 400 W electric heat pump (reversible for winter heating)
- Motor cooling: axial fan integrated with motor housing, 12V brushless blower
- Generator cooling: aluminium fin array + aperture in body panel for ram-air cooling above 20 km/h
- Thermal model: steady-state cabin temperature target 18–26°C at 35°C ambient, validated via CFD

10. VEHICLE MASS BUDGET

Mass is the single most important engineering parameter for the A6. Every kilogram added increases power demand and reduces range. The following is the engineering mass allocation:

Assembly / System	Target Mass (kg)	Notes
Space-frame chassis	60 kg	4130 steel tubular structure

Assembly / System	Target Mass (kg)	Notes
Body panels (aluminium/composite)	25 kg	Glazing included
Suspension (4 corners)	28 kg	Arms, springs, dampers, hubs
Wheels & Tyres (4×)	20 kg	13" alloy + narrow tyre
Pedal drivetrain (4 stations)	18 kg	Cranks, chains, flywheel, shaft
Generator	8 kg	PMSG 1 kW
Battery pack + BMS	22 kg	1.44 kWh LFP
Traction motor + gearbox	14 kg	PMSM 3 kW + 1:5 reduction
Power electronics (PCU, inverter)	6 kg	Including cabling
HVAC system	10 kg	Heat pump + ducts
Seats (4×)	24 kg	6 kg per ergonomic seat
Instrumentation, ECU, displays	5 kg	
Miscellaneous (fasteners, fluids, etc.)	10 kg	
TOTAL KERB WEIGHT	250 kg	Target — 300 kg tolerance
4 passengers @ 80 kg	320 kg	
GROSS VEHICLE WEIGHT	570–620 kg	Within L7e 550 kg limit: may need lightweight programme

Mass Risk Flag

The L7e classification cap is 400 kg unladen. At 250 kg the vehicle is borderline. Significant use of carbon-fibre reinforced polymer (CFRP) body panels (saving ~10 kg), titanium fasteners, and hollow-core aluminium chassis tubes would be required to meet L7e unladen mass. This adds significant cost. The alternative is to classify as a light motor vehicle and accept full type approval requirements.

11. PERFORMANCE PREDICTION & SIMULATION

Performance Metric	Predicted Value	Condition / Notes
Top Speed	50 km/h	Battery + 4 pax pedaling, flat road

Performance Metric	Predicted Value	Condition / Notes
Pedal-only cruise speed	~22 km/h	4 pax @ 150 W, flat road
0–30 km/h (sprint assist)	~12–15 seconds	Battery peak discharge + full pedal
Range (battery, 50 km/h)	~10–14 km	Battery only, no pedaling
Range (battery + pedal, 30 km/h)	~28–40 km	Combined mode, 4 pax moderate effort
Gradeability (5% slope)	~15 km/h sustained	Battery assist + 600 W pedal input
Gradeability (10% slope)	~8 km/h	Battery + max pedal — very demanding
Charge recovery (regen, 30→0 km/h)	~18–22% of kinetic energy	Typical urban stop event
Cabin noise (estimated)	< 55 dB(A) at 40 km/h	No combustion noise; wind/road dominant
CO2 per km (pedal + grid charge)	~0 gCO2/km (operational)	Scope 2 from grid excluded

12. ENGINEERING FEASIBILITY ASSESSMENT

The following matrix assesses each major challenge against its resolution pathway and associated risk level:

Challenge	Severity	Resolution Pathway
Power deficit at 50 km/h (5× gap)	HIGH	Battery provides primary motive power; pedaling = range extender. Reframe concept.
GVW exceeding L7e limits	MEDIUM-HIGH	CFRP body, aluminium chassis, aggressive lightweighting programme required.
Occupant fatigue over long trips	MEDIUM	Pedaling is opt-in; ECU allows any individual to stop without loss of vehicle mobility.
Drive shaft complexity with 4 inputs	MEDIUM	One-way clutches + bevel gear confluence is proven technology in industrial machinery.
Thermal comfort (4 metabolic heat sources)	MEDIUM	Dedicated HVAC heat pump; roof and side glazing solar-controlled coating.

Challenge	Severity	Resolution Pathway
Regulatory classification uncertainty	MEDIUM	Engage ARAI / TÜV / DVSA pre-submission for classification ruling before full development.
Cost of development vs market	HIGH	Unit cost estimated >INR 4–6 lakh; willingness-to-pay analysis required for target markets.
Long-term pedal mechanism wear	LOW-MEDIUM	Standard bicycle components; 3,000–5,000 km service interval for chains.

Feasibility Verdict

The A6 Architecture is technically feasible as a pedal-assisted electric vehicle (PAEV) — essentially an enclosed velomobile with a meaningful battery buffer. The concept is NOT feasible as a 'fully human-powered' vehicle at 50 km/h. The correct product framing is: an ultra-low-energy urban EV where passengers can meaningfully extend range through pedaling, with a gamified, health-positive HMI. This is commercially differentiated and physically sound.

13. RECOMMENDED DEVELOPMENT ROADMAP

Phase	Activities	Duration	Milestone
Phase 1: Concept Validation	Physics simulation, power budget model, regulatory pre-consultation, 1:5 scale wind tunnel model	3 months	Go/No-Go decision
Phase 2: Subsystem Prototyping	Build pedal-to-generator bench rig; validate 600 W input, 480 W electrical output; BMS selection; motor dyno test	6 months	Verified drivetrain efficiency
Phase 3: Rolling Chassis	Weld A6-GEMA 7 space-frame; integrate suspension, steering, brakes; dynamic handling test	6 months	< 290 kg kerb weight
Phase 4: Full Integration	Install pedal drivetrain + electrical system in rolling chassis; ECU tuning; cabin fit	6 months	Running vehicle
Phase 5: Validation & Approval	ARAI/TÜV type approval testing; safety crash test (scaled); homologation filing	9 months	Type Approval Certificate
Phase 6: Pilot Production	Build 10 pre-series units; fleet trial with fleet operators / universities	6 months	Market launch readiness

14. COMMERCIAL & MARKET ANALYSIS

14.1 Target Markets

- University & Corporate Campuses: closed-loop, low-speed, wellness-oriented commuting
- Eco-Tourism: pedal-powered sightseeing in heritage zones, national parks
- Urban Last-Mile Logistics (adapted variant): cargo deck replacing rear passenger seats
- Health & Wellness Resorts: paid 'fitness commute' product experience
- Developing Urban Markets: India, SE Asia — low-cost urban mobility with health differentiation

14.2 Estimated Bill of Materials (BOM) Cost

Space-frame chassis (welded)	INR 45,000 – 60,000
Body panels (aluminium + glazing)	INR 35,000 – 50,000
Pedal drivetrain (4 stations)	INR 20,000 – 30,000
Generator (1 kW PMSG)	INR 25,000 – 40,000
Battery pack + BMS (1.44 kWh LFP)	INR 60,000 – 90,000
Traction motor + inverter (3 kW)	INR 45,000 – 70,000
Suspension, brakes, tyres	INR 40,000 – 60,000
Seats, interiors, HVAC	INR 30,000 – 50,000
ECU, sensors, wiring	INR 20,000 – 35,000
Assembly labour (50 hrs @ INR 500/hr)	INR 25,000
ESTIMATED TOTAL BOM (pilot scale)	INR 3.45 – 5.10 Lakh
Suggested retail (3× BOM at pilot stage)	INR 10 – 16 Lakh

15. CONCLUSIONS & RECOMMENDATIONS

The A6 Architecture represents a genuinely innovative concept at the intersection of human-powered mobility and electric vehicle technology. This study reaches the following engineering conclusions:

1. The vehicle cannot sustain 50 km/h on pedal power alone. At four passengers $\times$ 150 W, available tractive power is $\sim$ 410 W versus 2,138 W required. The battery must be the primary energy source for cruising speed.
2. Reframed as a Pedal-Assisted EV (PAEV), the concept is fully viable. Pedaling contributes meaningfully at lower speeds (< 25 km/h) and extends range by 30–50% over battery-only operation.
3. The mechanical confluence of four independent crank inputs to a single drive shaft is engineering-feasible using proven industrial one-way clutch and chain-drive technology.
4. The 1.44 kWh LFP battery pack provides adequate urban-range performance (25–40 km in combined mode) while remaining within mass, cost, and safety constraints.
5. Regulatory classification as L7e (Europe) or Quadricycle (India AIS-138) is the appropriate target; early pre-consultation with homologation authorities is strongly recommended before committing to final design.
6. The estimated pilot-scale BOM of INR 3.5–5 lakh yields a retail price of INR 10–16 lakh. This is competitive with entry-level electric three-wheelers and is justifiable for premium wellness/eco applications.
7. The recommended next step is a 6-month Phase 1 effort: physics bench testing of the pedal-to-generator drivetrain, regulatory pre-consultation, and a detailed FEA mass analysis of the A6-GEMA 7 chassis.

Final Engineering Recommendation

PROCEED TO PHASE 1 with revised concept framing as a Pedal-Assisted Urban EV. The A6 Architecture is best positioned as the world's first production pedal-electric quadricycle — a wellness-focused urban mobility product where passenger activity directly and measurably extends vehicle range. This is a compelling, defensible product story grounded in sound physics.

APPENDIX A: KEY ENGINEERING STANDARDS REFERENCED

- ECE R100 Rev. 3 — Electric Power Train Safety (Battery, HV System)
- AIS-138 (Part 1 & 2) — Electric Vehicle Type Approval, India
- ISO 26262 — Functional Safety for Road Vehicles
- ISO 6469-3 — Electric vehicle safety — Protection of persons against electric hazards
- EN 15194 — Cycles: Electrically power assisted cycles (EPAC)
- FMVSS 305 — Electric-powered vehicles: Electrolyte spillage and electrical shock protection
- SAE J2344 — Guidelines for Electric Vehicle Safety
- BS EN 1078 — Helmets for pedal cyclists (reference only)

APPENDIX B: ABBREVIATIONS & GLOSSARY

PAEV	Pedal-Assisted Electric Vehicle
PMSG	Permanent Magnet Synchronous Generator
PMSM	Permanent Magnet Synchronous Motor
BMS	Battery Management System
PCU	Power Control Unit
FOC	Field-Oriented Control
LFP	Lithium Iron Phosphate (battery chemistry)
ECU	Electronic Control Unit
FEA	Finite Element Analysis
GVW	Gross Vehicle Weight
MTBF	Mean Time Between Failures
SOC	State of Charge
L7e	EU quadricycle class: heavy power quadricycle
ARAI	Automotive Research Association of India
TÜV	Technischer Überwachungsverein (German type approval body)
Crr	Rolling Resistance Coefficient
Cd	Coefficient of Aerodynamic Drag

— End of Document — A6-ENG-001-REV1 —